

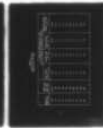
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**BREAK-EVEN ANALYSIS OF VADS,  
M163, ANTENNA PROTECTIVE DEVICE**

RICHARD D. HUSSON

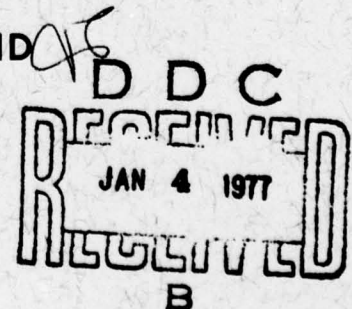
DAVID M. JOHNSON

JULY 1976

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This note presents a break-even analysis conducted to determine how much can be spent (per device) for an antenna protection device for the radar on the Vulcan M163 System. The present value of costs without a protective device was equated to the present value of estimated costs with a protective device. This analysis gives the maximum amounts that can be spent on protective devices for varying degrees of protection.		

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## I. INTRODUCTION

Based upon a need to evaluate design alternatives, Rock Island Arsenal Rodman Laboratory (SARRI-LW-P) requested that the HQ, ARMCOM Systems Analysis Directorate conduct an analysis, "to determine how much money can be spent per device for an antenna protection device for the radar on the Vulcan M163 System." In their request, SARRI-LW-P estimated that antenna losses were one per month and the cost of an antenna assembly is \$14,000. The number of M163 systems in the fleet (380) and the estimated service life (25 years) were likewise given. Also, a sensitivity analysis with respect to variation in unit failure rates was requested.

In response to this request, the present value of costs without a protective device (present situation) was equated to the present value of estimated costs with a protective device. This analysis, thus, gives the maximum amounts that can be spent on protective devices for varying degrees of protection. When using the results of this study, it must be kept in mind that the amounts stated are maximums and include both production and installation costs.

Section II states the problem that is to be answered. Section III states the assumptions made in conducting this analysis. Section IV describes the methodology used in the analysis. Section V gives the data inputs and sources used in the analysis. Section VI discusses the results. Section VII presents a sensitivity analysis to determine model responsiveness to changes in input data and to identify those variables which have the most impact upon the dependent variable--unit cost. Section VIII states the conclusions.

## II. PROBLEM STATEMENT

The problem is that the Department of the Army is spending \$135,000 per year to replace or repair the antenna assembly on Vulcan M163's. In an attempt to improve this situation, several protective devices were designed. Which of these designs will be used, if any, will depend to a great extent upon cost consideration. Thus, the purpose of this note is to answer the original question from Rock Island Arsenal Rodman Laboratory (SARRI-LW-P) -- "how much money can be spent per device for an antenna protective device for the radar on the Vulcan M163 System?"

## III. ASSUMPTIONS

- A. The M163 VADS will be in the inventory for the next 25 years.
- B. Design and initial production of protection devices will be accomplished during the first half of year one.
- C. Installation of protective devices will be accomplished during the second half of year one.



D. The system will continue to operate in the same or similar conditions and terrain.

E. Installation of an antenna protective device will not degrade system performance.

#### IV. METHODOLOGY

Since SARRI-LW-P was interested in the maximum amount of money which could be spent on the protective device, a break-even model was constructed. This model was used to compute unit cost values for various degrees of protective device effectiveness at which one is economically indifferent between continuing under the present situation or investing in the protection device. The degree of protection device effectiveness is defined as the percent of damage cost which can be prevented by use of the device.

A description of the model and inputs is as follows:

$$(A+B)Df_2 = (D+N'X)Df_1 + M'Df_1 + (N'P_f'X)Df_3 + (1-\epsilon)(A+B)Df_3$$

where:

A = annual cost to maintain feedhorn and reflector assembly

$$= R'F_1 + R(1-W_1)C_1 + R'W_1'C_r,$$

B = annual cost to maintain Unit #1

$$= U'F_2 + U(1-W_2)C_2 + U'W_2'C_u,$$

C<sub>1</sub> = unit cost to repair feedhorn & reflector,

C<sub>2</sub> = unit cost to repair Unit #1,

C<sub>r</sub> = unit cost of new feedhorn & reflector,

C<sub>u</sub> = unit cost of new Unit #1,

D = estimated development cost of protective device,

Df<sub>1</sub>, Df<sub>2</sub>, Df<sub>3</sub> = discount factors 10% years: 1, 1-SL, 2-SL (SL is service life),

F<sub>1</sub> = field cost to remove feedhorn & reflector,

F<sub>2</sub> = field cost to remove Unit #1,

- $M$  = first year maintenance of system based upon installation of protective device during second 6 months of first year  

$$= .25(N \cdot P_f \cdot X) + .75(A+B),$$
 $N$  = number of protective devices procured and installed,  
 $P_f$  = failure rate of protective device,  
 $R$  = number of feedhorn & reflectors damaged per year,  
 $U$  = number of Unit #1's damaged per year,  
 $W_1$  = washout rate of feedhorn & reflector,  
 $W_2$  = washout rate of Unit #1,  
 $X$  = unit cost to produce and install protective device = unknown,  
 $\epsilon$  = degree of protective device effectiveness - range 0-100%.

#### V. DATA

The following data definitions and sources were used in this analysis.

- $C_1$  = unit cost to repair feedhorn & reflector = \$387.  
 $C_2$  = unit cost to repair Unit #1 = \$3,018.  
 $C_r$  = unit cost of new feedhorn & reflector = \$1,652.  
 $C_u$  = unit cost of new Unit #1 = \$13,750.  
 $D$  = estimated development cost of protective device = \$75,000.  
 $F_1$  = field cost to remove feedhorn & reflector = \$3.65.  
 $F_2$  = field cost to remove Unit #1 = \$10.95.  
 $N$  = number of protective devices procured and installed = 380.  
 $P_f$  = failure rate of protective devices = 10%.  
 $R$  = number of feedhorns & reflectors damaged per year = 72.  
 $U$  = number of Unit #1's damaged per year = 12.



$W_1$  = washout rate (% of damaged units that are unreparable) of feedhorn & reflector = 70%.

$W_2$  = washout rate of Unit #1 = 2%.

The Vulcan antenna assembly consists of two major parts: the feedhorn and reflector and the Unit #1. Values for unit cost to repair feedhorn and reflector ( $C_1$ ), unit cost to repair Unit #1 ( $C_2$ ), unit cost of new feedhorn and reflector ( $C_r$ ), and unit cost of new Unit #1 ( $C_u$ ) were derived from using estimated average costs of previous production or repairs. These figures were provided by Red River Army Depot, Texarkana, Texas. SARRI-LW-P provided the estimates for the development cost of a protective device (D) and the number of protective devices to be procured (N). The field cost to remove feedhorn and reflector ( $F_1$ ) and the field cost to remove Unit #1 ( $F_2$ ) were derived from Material Maintenance Point estimates of MOS skill level and number of manhours needed to perform the work. Values for the number of feedhorn and reflectors damaged per year ( $R_1$ ), the number of Unit #1's damaged per year (U), the washout rate of feedhorn and reflectors ( $W_1$ ), and the washout rate of Unit #1's ( $W_2$ ) were estimated from historical data. The bulk of these estimates were obtained from Red River Army Depot and checked against available maintenance reports to determine the validity of the figures. The discount factors  $Df_1$ ,  $Df_2$ , and  $Df_3$  were taken from AR 37-13. SARRI-LW-P stated in the original request that a 25-year service life should be used in the analysis. Given the time that the M163 has been in the inventory, this figure seems possibly high; thus, results were calculated for 20 and 15 year service lives also. This and other variations in the inputs are discussed in Section VII, Sensitivity Analysis.

## VI. RESULTS

Table 1 presents the break-even unit cost values for given degrees of protective device effectiveness for service lives of 15, 20, and 25 years. Figure 1 is a graphical presentation of these same results. Any unit cost effectiveness value which falls in the area below the appropriate service life curve is economically advantageous. If, upon evaluating design alternatives, it is found that more than one falls below the curve, a more extensive economic analysis should be conducted to determine which is the best alternative.

## VII. SENSITIVITY ANALYSIS

Sensitivity analysis was conducted to determine model responsiveness to changes in data input and identify those independent variables which have the most significant impact upon the dependent variable-unit cost. The effect of the major independent variables was measured by increasing their value by a factor of 10% while holding all other independent variables constant and observing the percentage change in the dependent variable. Tables 2, 3, and 4 show the results of these analyses for given degrees of protective device effectiveness and service lives of 15, 20, and 25 years, respectively.

As can be seen, the number of items damaged per period and the unit cost of the damaged equipment have the most significant impact upon the unit cost of the protection device. Historical data from prior procurements and NICP/NMP records should, however, provide reasonably accurate value for these variables.

#### VIII. CONCLUSIONS

Based upon degree of protection and system service life, the break-even unit costs range from \$81 to \$1550. By specifying the degree of protection desired/achieved and the expected service life of the M163 VADS, the break-even unit cost can be determined either from Table 1 or by solving the model equation for values not included in the table.

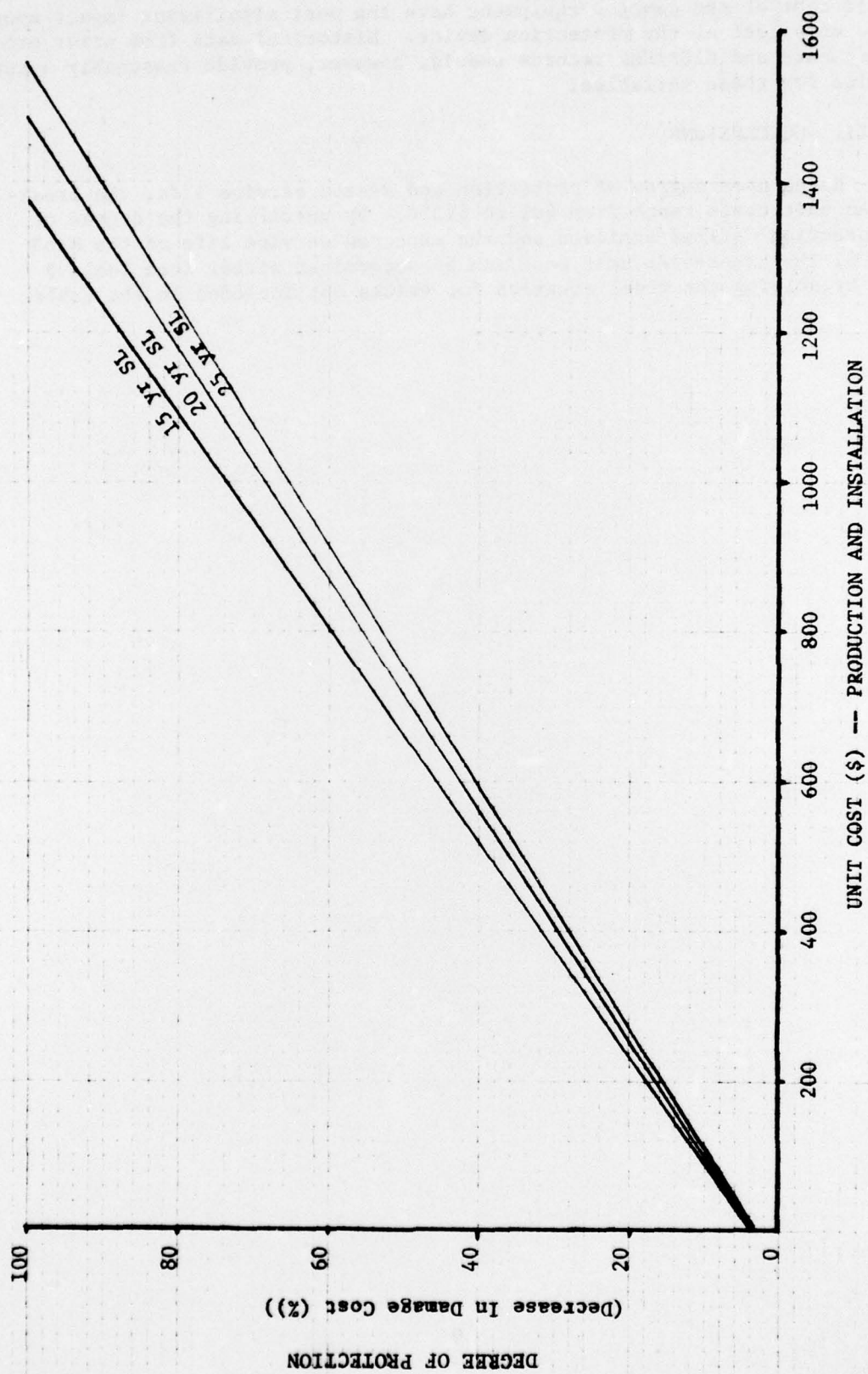


Figure 1. M163 Antenna Protection Device Unit Cost vs. Degree of Protection



TABLE 1  
BREAK-EVEN UNIT COST FOR GIVEN  
DEGREE OF PROTECTION AND SERVICE LIFE

Degree of Protection %	15 Year Life Break-Even Unit Cost \$	20 Year Life Break-Even Unit Cost \$	25 Year Life Break-Even Unit Cost \$
10	81	95	103
20	225	250	264
30	369	404	424
40	512	559	585
50	656	714	746
60	800	868	907
70	944	1,023	1,068
80	1,088	1,178	1,228
90	1,232	1,332	1,389
100	1,376	1,487	1,550

TABLE 2  
SENSITIVITY ANALYSIS  
(SERVICE LIFE 15 YEARS)

DEGREE OF PROTECTION	BREAK-EVEN UNIT COST BASE CASE	% CHANGE IN-BREAK EVEN UNIT COST GIVEN 10% CHANGE IN INDEPENDENT VARIABLE			
		UNIT REPAIR COSTS ( $C_1, C_2$ )	WASHOUT RATE ( $W_1, W_2$ )	NEW EQUIPMENT COST ( $C_r, C_u$ )	NUMBER OF UNITS DAMAGED PER YEAR ( $R, U$ )
10%	\$ 81	7.4%	12.3%	14.8%	22.2%
20	225	4.9	7.6	9.8	13.8
30	369	4.3	6.5	8.4	11.9
40	512	4.1	6.3	8.2	11.5
50	656	4.0	5.9	7.8	11.0
60	800	3.9	5.9	7.6	10.6
70	944	3.8	5.7	7.4	10.5
80	1088	3.7	5.6	7.4	10.3
90	1232	3.7	5.5	7.2	10.1
100	1376	3.6	5.5	7.1	10.1

TABLE 3  
SENSITIVITY ANALYSIS  
(SERVICE LIFE 20 YEARS)

DEGREE OF PROTECTION	BREAK-EVEN UNIT COST BASE CASE	% CHANGE IN BREAK-EVEN UNIT COST GIVEN 10% CHANGE IN INDEPENDENT VARIABLE			
		UNIT REPAIR COSTS ( $C_1, C_2$ )	WASHOUT RATE ( $W_1, W_2$ )	NEW EQUIPMENT COST ( $C_r, C_u$ )	NUMBER OF UNITS DAMAGED PER YEAR ( $R, U$ )
10%	\$ 95	7.4%	10.5%	13.7%	20.0%
20	250	4.4	7.2	9.2	13.2
30	404	4.2	6.4	8.4	11.9
40	559	3.9	6.1	7.9	11.1
50	714	3.8	5.7	7.6	10.6
60	868	3.8	5.7	7.5	10.5
70	1023	3.7	5.6	7.3	10.3
80	1178	3.7	5.5	7.1	10.1
90	1332	3.7	5.5	7.1	10.1
100	1487	3.6	5.4	7.1	10.0



TABLE 4  
SENSITIVITY ANALYSIS  
(SERVICE LIFE 25 YEARS)

DEGREE OF PROTECTION	BREAK-EVEN UNIT COST BASE CASE	% CHANGE IN BREAK-EVEN UNIT COST GIVEN 10% CHANGE IN INDEPENDENT VARIABLE			
		UNIT REPAIR COSTS ( $C_1, C_2$ )	WASHOUT RATE ( $W_1, W_2$ )	NEW EQUIPMENT COST ( $C_r, C_u$ )	NUMBER OF UNITS DAMAGED PER YEAR ( $R, U$ )
10%	\$ 103	6.8%	9.7%	13.6%	18.4%
20	264	4.5	6.8	9.1	12.9
30	424	4.2	6.4	8.3	11.8
40	585	3.9	6.0	7.9	10.9
50	746	3.9	5.8	7.5	10.5
60	907	3.7	5.6	7.4	10.4
70	1068	3.7	5.5	7.2	10.2
80	1228	3.7	5.5	7.2	10.1
90	1389	3.6	5.5	7.1	10.0
100	1550	3.6	5.4	7.0	9.9

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